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π^0 PHOTOPRODUCTION ON PROTON AT BACKWARD ANGLES BETWEEN 700 MeV AND 1150 MeV

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π^0 photoproduction cross sections on proton have been measured at π^0 c.m. angles between 115° and 180° and between 700 MeV and 1150 MeV photon energies by detecting only the recoil proton. Our results show clearly a peak at 135° around 1000 MeV energies as predicted by Walker's partial wave analysis.

The $\gamma + p \rightarrow p + \pi^0$ reaction is studied by detecting only the recoil proton. The kinematics of the above reaction are completely determined by the knowledge of the proton scattering angle and

momentum thus the γ energy is known. Since the energy spectrum of the bremsstrahlung photons is continuous, our counting rate can be contaminated by spurious reactions which, in this case,

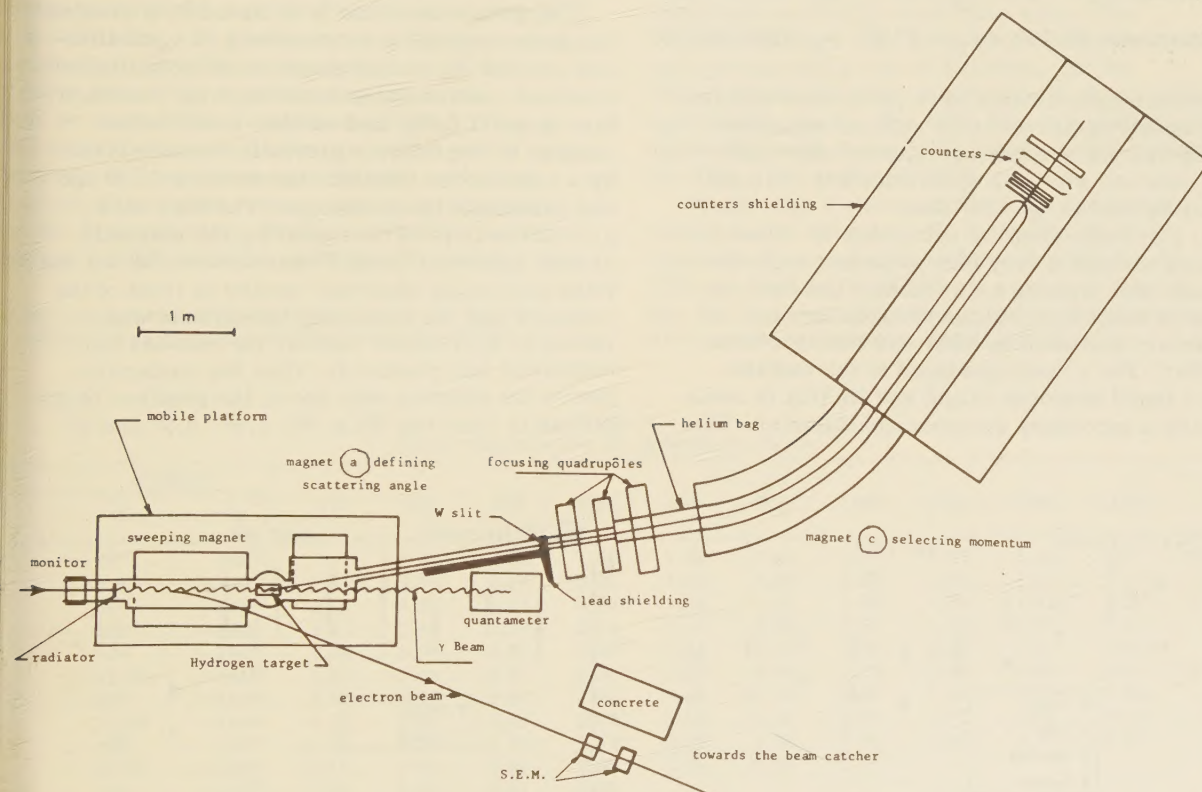


Fig. 1. First experimental setup.

are the Compton scattering, the 2π production and the so-called "ghost proton" production [2] (these last protons could be produced by a double reaction in the target as for instance a $\gamma + p \rightarrow n + \pi^+$ reaction followed by a $\pi^+ + p \rightarrow \pi^+ + p$ scattering). Our results give the sum of the π^0 and Compton production, but this last reaction [3] is known to be small with respect to the π^0 photo-production in this region. By keeping the electron energy close to the γ energy of single π^0 photo-production ($E_e - E_\gamma$ of the order of 30 MeV) the 2π contribution to the total counting rate is very low, of the order of a few per cent. Finally it is observed in our measurements that the "ghost proton" counting rate above the Compton threshold is also negligible and it is assumed that this result is still true for proton momenta corresponding to π^0 production.

Proton scattering angle θ_p and momentum p_p measurements were performed with two different magnetic spectrometers depending on the proton angle and momentum ranges, as follows:

Spectrometer I : $0^\circ \leq \theta_p \leq 20^\circ$ $p_p < 1500$ MeV/c

Spectrometer II: $15^\circ \leq \theta_p \leq 27.5^\circ$ $p_p < 1250$ MeV/c.

Absolute measurements were performed with the first spectrometer and only relative measurements with the second one. The 15° and 17.5° data obtained with both spectrometers are used to normalize the $\theta_p > 20^\circ$ data.

a) First experimental setup (fig. 1). After passing through a very thin secondary emission monitor and striking a Cu radiator the electron beam is swept by a magnet towards another secondary emission monitor and finally a beam catcher. The γ beam produced in the radiator hits a liquid hydrogen target and its flux is measured by a secondary emission quantameter. The

quantameter absolute calibration was performed just after each run using a radiator of precisely measured thickness and a Faraday cup to measure the electron current; its linearity versus γ energy and its stability were checked during the run with the two secondary emission monitors.

The magnetic spectrometer consists in three parts: the particles to be analyzed are deflected by a uniform field magnet "a" towards a set of three quadrupoles which focus them. Finally the momentum analysis is achieved by a 45° bending magnet "c". The sweeping magnet, the target and the magnet "a" can be moved with respect to the quadrupoles and magnet "c" depending on the analyzed scattering angle. Data were thus taken around three average positions corresponding respectively to 2.5° , 10° and 17.5° . Thus by a slight change of the magnetic field in "a" angles from 0° to 5° , 7.5° to 12.5° and 15° to 20° were respectively available at the three positions. The solid angle is defined by a 5 cm thick tungsten slit put in front of the first quadrupole: the horizontal and vertical acceptances were respectively of the order of 15 m rad and 30 m rad.

The proton detection is achieved by a counter telescope consisting successively of a scintillation counter A, an hodoscope of six scintillation counters, each counter covering a $\Delta p/p$ momentum range of 0.8%, and another scintillation counter B; therefore a proton is characterized by a coincidence between the counters A, B and one counter of the hodoscope. The high background due to positrons entering the magnetic system between 0° and 5° was lowered by a 1 cm thick aluminium absorber located in front of the counters and the remaining background was vetoed by a Čerenkov counter put between the hodoscope and counter B. Then the contamination to the counting rate due to the positron background is less than 2% at 0° , 1.5° , 3.5° and 5°

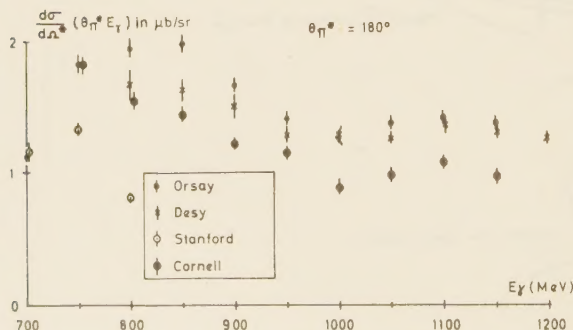


Fig. 2a. 180° data versus γ energy.

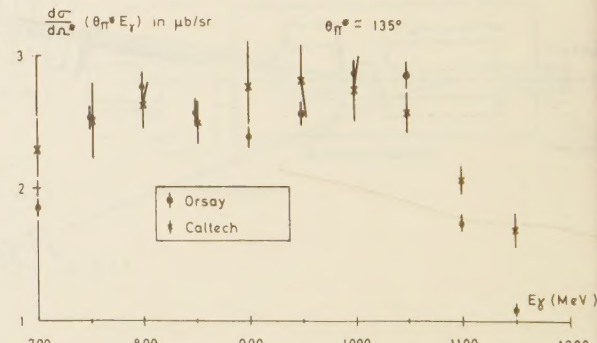


Fig. 2b. 135° data versus γ energy.

and quite negligible at other angles. The proton nuclear absorption in the absorber and the Čerenkov counter was measured in a preliminary run.

b) Second setup. As the second setup is very similar to the first one described above, we give here only the differences between them. The magnetic analysis of the scattered protons is done by a rotating double focusing magnet [4]. It was not possible here to use a quantameter and thus only relative measurements were performed. The proton telescope is quite similar to that above except for the Čerenkov counter which was of no use at the analysed scattering angles *.

In order to extract the π^0 cross section from the six measured counting rates of the hodoscope we proceed in the following way. In a first stage corrections have to be made to the experimental proton yield in order to get the true proton yield due to the hydrogen of the target. These were mainly the empty target subtraction, the correction for proton absorption in the target and in the counters, and the correction for electronics dead time. So these six corrected proton yields correspond to the sum of π^0 production, Compton scattering, 2π production and "ghost proton" production. As it has already been said the "ghost proton" process is very low in our case and we neglect the Compton scattering. Then in the second stage we fit the six proton yields by a bremsstrahlung curve normalized to π^0 cross section plus a phase space curve corresponding to the 2π production. When the π^0 cross section varies quickly with the γ energy at given θ_p , the

bremsstrahlung curve is multiplied by a factor taking into account this variation: this occurs for γ energies lower than 800 MeV and higher than 1050 MeV at angle θ_p greater than 5° .

The results are given in table 1. The statistical error is mainly due to the statistical counting rate and to the determination of the difference between electron and γ energies; it is about 4% for $\theta_p \leq 20^\circ$ and about 5% for other angles. Furthermore the systematic error in the data is estimated at 5%. This last error comes mainly from the error in the determination of the number of the target protons (1.5%), from the error on solid angle (2.5%), from the error in $\Delta p/p$ of each counter (2.5%), from the error in the absolute calibration of the quantameter (1.5%), and from the error in the bremsstrahlung curve (2%).

The existing data in the energy range covered by our measurements were taken either at $\theta_\pi^* < 135^\circ$ or at $\theta_\pi^* = 180^\circ$. So in fig. 2a our 180° results are compared to those of Desy [6], Cornell [7] and Stanford [8]. The agreement with Desy results is good except for γ energies of 800 MeV and 850 MeV. The Cornell data are lying systematically lower than ours. The 700 MeV Orsay result is in good agreement with the corresponding one of Stanford, but the 750 MeV and 800 MeV results are in strong disagreement. On fig. 2b, 135° data are plotted: the agreement with Caltech [9] results is good except for 700, 1100 and 1150 MeV.

Finally fig. 3 shows some of the angular distributions we obtained. We have also plotted theoretical curves of Schmidt and Schwiderski [10] and Walker [1] (Walker's curves plotted on the 900 MeV and 1150 MeV angular distributions are curves computed respectively for $E_\gamma =$

* Both apparatus were also used with slight modifications in an η photoproduction experiment [5].

Table 1
Cross sections in c.m. system in $\mu\text{b}/\text{sr}$

E (MeV)											
θ_p	θ_π^*	700	750	800	850	900	950	1000	1050	1100	1150
0°	180°		1.83	1.95	1.99	1.66	1.41	1.27	1.37	1.42	1.37
2.5° *	$\sim 174^\circ$	1.11	1.84	2.03	2.00	1.82	1.45	1.35	1.50	1.33	1.30
5°	$\sim 169^\circ$	1.18	1.94	2.04	2.03	1.90	1.62	1.61	1.69	1.29	1.26
7.5°	$\sim 162^\circ$	1.17	2.00	2.30	2.23	2.14	2.05	2.00	1.79	1.37	1.20
10°	$\sim 156^\circ$	1.48	2.03	2.28	2.46	2.43	2.35	2.38	2.18	1.51	1.09
12.5°	$\sim 151^\circ$	1.31	2.08	2.41	2.54	2.52	2.59	2.76	2.30	1.61	1.16
15°	$\sim 145^\circ$	1.52	2.18	2.66	2.58	2.45	2.72	2.91	2.50	1.69	1.15
17.5°	$\sim 140^\circ$	1.70	2.39	2.67	2.63	2.52	2.67	3.04	2.67	1.64	1.15
20°	$\sim 134^\circ$	1.85	2.53	2.77	2.57	2.39	2.56	2.86	2.85	1.73	1.09
22.5°	$\sim 128^\circ$	2.11	2.66	2.83	2.58	2.18	2.58	2.71			
25°	$\sim 122^\circ$	2.22	2.78	2.91	2.48						
27.5°	$\sim 116^\circ$	2.42	3.00	3.30	2.58						

* The 2.5° results are the average of 1.5° and 3.5° data.

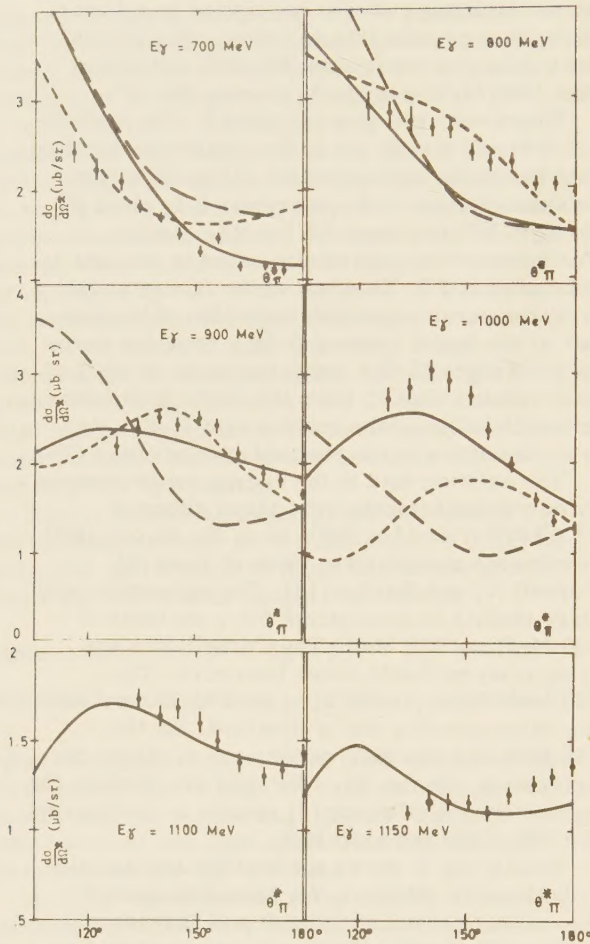


Fig. 3. Angular distributions at $E_\gamma = 700, 800, 900, 1000, 1100$ and 1150 MeV.

• Orsay data, — Walker's curve, --- curve a),
 ---- curve b) of Schmidt-Schwiderski.

$= 920$ MeV and $E_\gamma = 1175$ MeV). Schmidt and Schwiderski solve the dispersion relations for the photoproduction amplitude by assuming that only the imaginary part of the M_1^+ magnetic dipole, corresponding to the P_{33} resonance, contributes to the imaginary part of the total amplitude (moreover $\text{Im } M_1^+$ is computed in the static limit). Furthermore, in the energy range of the D_{13} and F_{15} resonances, i.e. from 800 MeV to 1100 MeV, they add to the amplitude resonant multipoles M_2^- , E_2^- of the D_{13} resonance and M_3^+ , E_3^+ multipoles of the F_{15} resonance; then they get curves a) for the π^0 photoproduction. The curves b) are obtained by adding also multipoles corresponding to the D_{15} resonance.

Walker's model, similar to the isobaric model [11], is an extension of photoproduction analysis done by Chau et al. [12] between 600 MeV and 800 MeV*. This model is more phenomenological in the sense that each resonant multipole is approximated by a B.W. curve whose position and width are given by π -N scattering results but whose height has to be determined by the pion photoproduction results. Furthermore some small corrections to the small l waves are needed. It is clear from fig. 3 that, although the quantitative agreement is not good, the qualitative features of the angular distributions are well described by Walker's model: this model does predict a maximum in the angular distribution near 135° in the D_{15} , F_{15} energy region (900-1050 MeV). The disagreement with Schmidt and Schwiderski curves is greater.

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* As the result of Chau et al. is very close to Walker's we do not represent their curves on fig. 3.

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